

**CIRCUIT AND METHOD FOR THE SECURING OF A COPROCESSOR
DEDICATED TO CRYPTOGRAPHY**

Field of the Invention

The present invention relates to cryptography, and, more particularly, the invention relates to a circuit and a method for securing the
5 loading of a digital key and/or message to be encrypted or decrypted.

Background of the Invention

The field of the invention is cryptology. Cryptology can be defined as the science of concealing
10 information. It is, along with the physical security of the components and of exploiting systems, a critical characteristic of chip card security.

Cryptology encompasses both cryptography, which is the art of encrypting and decrypting messages,
15 and cryptanalysis which is the art of breaking secret codes. The encryption of messages includes the conversion of information by a secret convention. The conversion function constitutes the cryptographic algorithm whose secret lies in parameters known as
20 keys. The reverse operation, which is the decrypting of the message, requires a knowledge of these keys.

In chip cards, cryptography implements various mechanisms aimed at ensuring either the

confidentiality of the information or the authentication of the cards or users or again the signature of the messages. All the means implementing cryptography form a cryptography system.

5 Figure 1 is a simplified diagram of a typical cryptography system. In this figure, a non-encrypted message is transmitted from a transmission unit 1 to a reception unit 2 in the form of an encrypted message. In the transmission unit 1, the non-encrypted message
10 is converted by an algorithm A which is a function of an encryption key C1. In the reception unit 2, the information received is decrypted by a reverse algorithm A^{-1} which uses a decryption key C2 in order to recover the non-encrypted message. In this specific
15 case, i.e. when an encryption and decryption algorithm is used, the encryption key and the decryption key are identical. A message can thus be transmitted between a sending unit and a reception unit on an unsecured channel. Only an authorized user holding the secret
20 decryption key can decode the encrypted message.

 The decryption operation implies that the encryption algorithm is a reversible algorithm. This condition is not necessary for example during an authentication operation. Indeed, certain
25 authentication mechanisms use one and the same algorithm at both the sending and the reception of a message. The choice of an encryption algorithm for a chip card depends on the type of security service expected, the performance and above all the cost of the
30 resources needed to install this algorithm. This cost depends on the size of the RAM and ROM type memories.

 Indeed, the use of bulky algorithms very quickly increases the price of chip cards. An encryption algorithm widely used in chip cards is the
35 DES (Data Encryption System) algorithm according to the

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15 The digital keys used by the electronic
components to encrypt or decrypt messages, especially
in chip card microcomputers, are therefore essential
for the confidentiality of the data elements conveyed.
Anybody possessing the digital key associated with an
20 encryption algorithm or decryption algorithm can access
data not intended for him or her.

In Figure 3, a memory module 30 is connected to a battery of input/output registers 32 by a two-way link 31. The battery of input/output registers 32 include elementary registers which, for example, have a
35 memory capacity of one eight-bit byte (hereinafter, in

the present document, the term "byte" shall be defined as an eight-bit byte). A multiplexer 34 distributes the data contained in the battery of input/output registers 32 between elementary registers of an input register 36 and a key register 38. A control module 40 manages all the operations performed by the memory module 30, the battery of input/output registers 32 and the multiplexer 34. The control module 40 furthermore ensures that the data elements to be encrypted or decrypted sent by the memory module 30 are transmitted into the input register 36 by a first communication bus B1 and that the data relative to the digital key is transmitted into the key register 38 by a second communications bus B2.

There are several possible types of operation for the transmission of data from the battery of input/output registers 32 to the input register 36 and the key register 38. A first mode of transmission may be the following: all the elementary registers of the battery of input/output registers 32 are filled with data elements coming from the memory module 30. Only then is the totality of the information contained in the battery of input/output registers 32 transmitted into each of the appropriate elementary registers of the input register 36 or, as the case may be, into each of the appropriate elementary registers of the key register 38.

Another possible mode of transmission is the following one: whenever a register of the battery of input/output registers is loaded from the memory module 30, it is immediately transmitted through the multiplexer 34 to an appropriate elementary register of the input register 36 or the key register 38. In any case, a processing module 42 working by an encryption or decryption algorithm requires all the data,

5 is also managed by the control unit 40.

43. With all these data elements, the processing module 42 is capable of transmitting a message processed into an output register 44 by means of a link 45. The data elements contained in the output register 44 can then be transmitted to the memory module 30 through the multiplexer 34, the battery of input/output registers 32 and a third communications bus B3 which exchanges data between the output register 44 and the multiplexer 34.

25 encryption or decryption system.

35 multiplexer 34, between the multiplexer 34 and the

different input registers 36, key registers 38 and output registers 44 or again between the different input and output registers and the processing module 42.

5 The digital key may thus be discovered as a result of an accumulation of measurements of the electrical signals referred to here above and a statistical study of these measurements. The component may for example use the digital key in the situation
10 shown in Figure 3. For example, in the case where the component performs an encryption operation, to perform an operation of this kind, the component needs to load the encryption key from an internal memory module. It may thus be authenticated as being a legitimate
15 component entitled to perform the operation. Thus, if the component is observed when it is known to be performing an operation to load the key, then it is possible, by recording the information conveyed by the electrical signals brought into play, to arrive at
20 knowledge on the digital encryption key. Once this key is known, it is very easy to reproduce the behavior of the legitimate component and subsequently perform operations initially prohibited to some user or another.

25 Another exemplary case may pose a problem on the visibility of the information flowing in the form of electrical signals. Indeed, apart from information on the digital key, it is also possible, by the study of certain electrical signals, especially between the
30 output of the processing module and the memory module, to know the processed result recovered by the component in its memory module. The knowledge of only the encryption or decryption result, possibly in association with the knowledge of the original message
35 to be encrypted or decrypted, may be enough to thwart

the security provided by the confidentiality of a digital key. Indeed, it is enough to send a component the processed result expected as a function of the initial message to enable the performance of operations
5 that were not authorized at the outset.

Summary of the Invention

It is an object of the present invention to overcome the problems that have just been described. To this end, the invention provides an electronic
10 circuit for the securing of a coprocessor dedicated to cryptography that ensures the non-visibility, with respect to a study of electrical signals during data transfers, of the digital key or of the result of an encryption or decryption operation.

15 To achieve these goals, the invention includes the use of an additional register, called a scrambling register, in the battery of input/output registers 32 of the circuit described in Figure 3. This additional register is filled by what are called
20 scrambling bits, randomly at instants also chosen randomly during the loading of the digital key into the battery of input/output registers. A random factor is thus introduced. This random factor enables the elimination of a part of the visibility, to the outside
25 world, of the behavior of the component and therefore of the data elements that it is processing. An analysis of the electrical signals associated with the data elements being processed can no longer be effective in obtaining possession of confidential
30 information.

The loading of the scrambling register is a dummy operation that has no effect on the loading of the data essential to the operation of the encryption

or decryption operations. The loading of very highly sensitive data is thus secured.

The invention relates to an electronic circuit for the securing of a coprocessor dedicated to cryptography comprising a memory module, a battery of input/output registers connected to the memory module by a two-way link, and a multiplexer to carry out a transfer of data between the battery of input/output registers and an input register or a key register. The input register and the key register respectively receive the data elements of a message to be processed by an encryption or decryption operation and the data elements of an encryption or decryption digital key.

The circuit also includes a processing module to perform an encryption or decryption operation accepting, at a first input, the messages to be processed contained in the input register and, at a second input, the digital key contained in the key register to process the message to be processed. Also, a control module is included to manage the operations performed by the memory module, the battery of input/output registers, the multiplexer and the processing module. Furthermore, the circuit has an output register to transmit the result of an encryption or decryption operation to the battery of input/output registers through the multiplexer. The battery of input/output registers comprises a scrambling register to receive scrambling bits foreign to the message to be encrypted or decrypted and/or to the digital key.

According to one embodiment of the invention, the circuit includes an accessory input register connected to the processing module and to the multiplexer to receive the scrambling bits sent directly by the processing module or coming from the memory module. The phrase "scrambling bits coming from

the memory module" is understood to mean the scrambling bits could have been transmitted to other elements of the circuit before reaching the accessory input register.

5 According to one particular embodiment, the circuit according to the invention includes the scrambling bits being generated randomly by the memory module or the processing module. In the preferred applications of the invention, the scrambling bits are
10 produced in the form of eight-bit bytes.

Another object of the invention is to provide a method for the securing of a coprocessor dedicated to cryptography comprising the steps of: transmitting data by a two-way link from a memory module to a battery of
15 input/output registers, transmitting, through a multiplexer, from the battery of input/output registers respectively to an input register and to a key register, respectively data corresponding to a message to be processed by an encryption or decryption
20 operation and data corresponding to an encryption or decryption digital key, and processing the message to be processed by a processing module accepting, at a first input, the data elements coming from the input register and, at a second input, the data elements
25 coming from the key register and giving the data elements corresponding to the processed message to the output register. The method according to the invention also includes the step of the transmission, to a scrambling register of the battery of input/output
30 registers, of the scrambling bits foreign to the message to be processed and the transmission, to the digital key, of the scrambling bits being sent directly by the memory module or coming from the processing module.

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Brief Description of the Drawings

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Figure 2 illustrates a conventional example of dynamic verification of the validity of the encryption of a message transmitted after encryption;

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Detailed Description of the Preferred Embodiments

Figure 4 shows the same elements as in the electronic circuit described in Figure 3: a memory module 30, a battery of input/output registers 32, a multiplexer 34, an input register 36, a key register 38, a control module 40, a processing module 42, and an output register 44. The figure also shows the same electrical links or communication buses as in the circuit described with reference to Figure 3.

10 The circuit according to the invention can be distinguished from the prior art circuit shown in Figure 3, by the presence of an additional register 50, called a scrambling register, in the battery of input/output registers. Unlike the other registers of
15 the battery of input/output registers, the scrambling register 50 is not designed to receive data elements pertaining to the message to be processed or to the digital key. The scrambling register 50 is designed to receive a certain number of bits called scrambling bits
20 that are designed to secure the loading of a digital key or a processed message into the battery of input/output registers 32.

In one particular embodiment of the invention, the scrambling register 50 may contain eight bits. Its size therefore is one byte. This example however is not restrictive and the size of the scrambling register 50 may differ according to the embodiments of the circuit according to the invention. For the sake of simplicity, the description shall hereinafter be limited to the case where the scrambling register 50 has the size of one byte. A two-way link 52 transfers data between the scrambling register 50 and the multiplexer 34.

According to a preferred embodiment of the
35 invention, an accessory input register 54 is connected

firstly to the multiplexer 34, by a two-way link 56,
and secondly to the encryption module 42, by a two-way
link 58. Preferably, the accessory input register 54
has the same size as the scrambling register 50. The
5 accessory register 54 is indeed designed to receive or
send scrambling bits from or to the scrambling register
50. However there is no major drawback if the
accessory input register 54 has a size different from
that of the scrambling register 50.

10 The operation of the circuit according to one
particular embodiment of the invention is as follows.
The memory module 30 loads a certain number of bits in
the form of bytes into the elementary register of the
battery of input/output registers 32. These bytes
15 correspond either to a message to be processed or to
the digital key. When the digital key is loaded from
the memory 30 into the input/output battery 32,
scrambling bits are sent randomly on the link 31. The
scrambling bits are then oriented to the scrambling
20 register 50 according to different operational modes
explained here above. The scrambling bits, like the
other data elements, may be transmitted by bytes.

A random number of scrambling bytes is
therefore sent between two bytes carrying information
25 on the digital key. Should the digital key have a size
of 8 bytes, a scrambling byte may be transmitted
between any two bytes encoding the digital key. A
scrambling byte may also be transmitted before the
first byte encoding the digital key or again after the
30 last byte encoding the digital key. Furthermore, a
random number of scrambling bytes may be sent during
one and the same loading of a digital key. In this
example, each scrambling byte sent is always oriented
towards the scrambling register 50, and each new

This is also the case for the scrambling bytes coming from the processing module 42 and received by the accessory input register 54. Thus, a person who tries to obtain the digital key fraudulently by the study of the electrical signals sent by the two-way link 31 is doomed to failure. Indeed, the electrical signals corresponding to the sending of the scrambling bytes will distort the statistical studies that would have led to the discovery of the digital key.

Just as the register 36 and the key register 38 may have a size similar to that of the register of the battery of input/output registers 32, it is enough for the accessory input register 54 to be of the minimum size needed to receive the data elements coming from the scrambling register 50. The two-way link 56 herein also ensures that any statistical study of the electrical signals exchanged between the multiplexer 34 and the input register 36 and key register 38 will be disturbed. In the same way, the study of the electrical signals between the input register 36 and the key register 38 is disturbed by the electrical signals conveyed by the two-way link 58 between the

accessory input register 54 and the processing module 42.

In the preferred embodiment of the invention, the accessory input register 54 has an address close to the addresses of the input register 36 or of the key register 38. A person studying the electrical signals exchanged on the different buses thus cannot perceive any obvious difference when the addresses of the addressee registers are conveyed. When the processing module 42 produces the encrypted message that it stores in the output register 44 by the link 45, it produces scrambling bits randomly and not necessarily for each encrypted operation. These scrambling bits are stored in the accessory input register 54 by the two-way link 58. The new scrambling bits are also transmitted through the multiplexer 34 to the battery of input/output registers 50 simultaneously with the transmission of the data elements contained in the output register 44 to the input/output register 32 through the multiplexer 34.

A piece of electrical scrambling information is thus present during the loading, into the memory module 30, of the result of the encryption or decryption operation. Thus, a person who might have knowledge of the message to be encrypted cannot obtain knowledge of the encryption result by a statistical study of the electrical signals conveyed on the different links that come into action.

The securing circuit and method according to the invention can be used for any encryption and decryption operation. The circuit and the method according to the invention therefore use an electrical scrambling signal for all sensitive data transfers needed to carry out an encryption or decryption operation with a digital key.

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